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A POINT-CONTACT TRANSISTER PULSE SHAPER

- USSR -

by Yu. I. Senatorov

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A POINT-CONTACT TRANSISTER PULSE SHAPER

/This is a translation of an article written by Yu. I. Senatorov published in Moscow, 1958, pages 3-22./

Description of the shaper's set-up

The pulse shaper's set-up is given in Fig. 1. The positive feed-back needed for its operation is built up on the internal resistance of the triode r_6 . This resistance is the resistance of the germanium transistor plate, which is the basis of the triode. In order to develop the regeneration, the resistance r_6 must not fall below a certain prescribed value.

Should the resistance r_6 be too small, an external resistance R_6, much larger than r_6 ($R_6 \simeq 1 \div 4$ kilo-ohm) while ($r_6 \approx 200 \div 600$ om) has to be added. The presence of N and S shaped characteristics of the triode, which produces the regeneration, depends not only on the resistance $R_6 = r_6 + R_6$, but also on the magnitudes $a, r_э, r_к, E_к, E_э$ and on the external elements of the set-up. For this reason the R_6 value of the set-up may vary within wide limits.

In one batch of point contact triodes C2G, C1E (released in October 1956) the magnitude r_6 was found to be sufficiently high to allow for the development of the pulse-former's set-up without the need of an external R_6. Absence of that external resistance R_6 affected favorably the absolute figure of the spread in the point of the upper bend of the N shaped characteristic of the triodes, for which point the voltage given in old set-ups amounted to $U'_э \approx R_6 \cdot I_{KO}$, where I_{KO} was the dark current; for that batch of triodes this I_{ko} varied within 1 -- 4 ma.

The dimimution of the spread in the coordinates of the points of the bend in the N shaped characteristic allows to leave the external elements of the set-up unchanged for many triodes of the batch. The percentage of triodes that were fit to work amounted to 70.

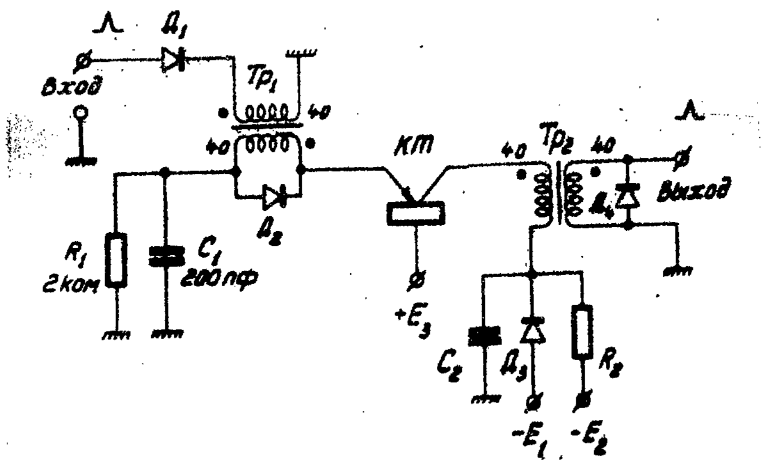

Fig. 1

At the same time, a correct selection of the elements of the set-up raises the reliability of its work in cases of certain deviation in the characteristics of the triode itself.

With the external resistance R_6 absent, the start signal is sent into the emitter's circuit. It is known* that this way of starting increases the time of the coordination period of the set-up by causing a delay (t_{zap}) of the exit pulse of the former in relation to the starting pulse. (For the set-up of Fig. 1 $t_{zap} = 0{,}15 \div 0{,}2$ microsec, which is most undesirable. This delay can be avoided by sending the starting signal into the circuit of the base. For this purpose a transformer is switched into the base. For this purpose a transformer is switched into the base of the triode, and one of its coils receives the signal in the proper phase. This results in a strong feed-back which in many cases generates certain pulses, and the latter are eliminated by the shunting of the transformer's windings with a small resistance. This, in its turn, leads to a weak entrance resistance of the set-up; and this complicates the coordination of the pulse-sharper with other elements. From this viewpoint the entrance resistance of the set-up R_{vkh} should exceed 0.8 kilo-ohms.

*See the thesis by Ye. V. Kostyukevich: "Investigation of the relaxation generators on point-contact crystalline triodes". 1956; Printing shop VVIA imeni Prof. N. E. Zhukovskiy.

The shunt's resistance amounts to 300-400 ohms for a transformer with a factor 1:1.

For this reason a set-up with a transformer in the base of the triode should be used in the cases in which the entrance resistance R_{vkh} need not exceed 400 ohms.

Another specific feature of the set-up described consists in the raised brush voltage $E = -30$ volt, which amounts to only 20 volt in the previous set-up, based upon triodes of the types C2G, C1E. This naturally leads to increased amplitude of the exit pulse. The direct feeding from the source of the current of the E_1 voltage of the brush circuit leads frequently to the heating up of the triode due to the excessive brush current and ruins the triode. Therefore the voltage E_1 is admitted through the sub-circuit R-diode-C, which uses a supplementary voltage source E_2 $(|E_2| > |E_1|)$. The sub-circuit E-diode-C puts a limit to the maximum current I_{max} which pass through the triode's collector even if the resistance of that collector were zero. A long-time operation of numerous triodes at the maximum current I_{max} of 10 ma and maximum voltage of -30v did not cause a single triode to be ruined. The period of voltage recovery upon the capacity C of that circuit has to be coordinated with the maximum frequency of the pulse-shaper's action.

The set-up of the pulse-shaper with point contact triode is shown in Fig. 1. The tasks of its elements are as follows:

1) The start of the set-up is accomplished by positive pulses passing through the transformer Tp_1. The amplitude of the starting pulses U_{zap} is greater than four volts. The minimum is above 1 volt, but at this minimum the set-up will not operate with each starting pulse. With U_{zap} less than 1 volt, the set-up will not react at all.

2) The diode D_1 lowers the back effect of the set-up upon the channel of the start.

3) The capacity C_1 is necessary for producing the current's throw into the emitter's circuit.

4) Resistance R_1 serves for the discharge of the capacity C_1. The time constant is $\tau = R_1C_1 = 0,4$ microsec.

5) The +0.5 volt of the voltage source E_3 protects the set-up from the parasitic signals as long as their voltage does not exceed 1 volt.

6) Both transformers Tr_1 and Tr_2 of the exit are built of identical material "oxy-fer 600". The coils are wound on two toroidal rings size 4 x 7 mm.

7) Diode D_4 cuts off the negative reject in the exit pulse. Depending on the magnitude of the loading resistance, an extra resistence can be thrown in in series with the diode D_4. Its value is adjusted to the case of a critical run of the transfer process in the transformer Tr_3.

8) The sub-circuit R_2-D_3-C_2 and the voltage source E_3 play the part of a limiter of the current passing through the triode.

9) Voltage source E_1 plays the part of the nominal voltage source in the circuit of the collector.

The power used during a stationary run in the resistance R_2 equals $P_{R_2} \approx \frac{(E_2 - E_1)^2}{R_2}$ and exceeds 2 - 4 times the amount consumed in the actual set-up when $E_1 = -30$ volt.

$$P_{cx} = E_1 \cdot I_{KO} \quad (P_{cx} \approx 0{,}12 \text{ em}),$$

where I_{ko} is the dark current of the triode.

Should the amplitude of the existing pulse, as taken from the loading characteristic of the pulse shaper (Fig. 2) be sufficient, the same set-up of feeding the collector circuit might be recommended provided $E_1 = -20$ volt. Maximum frequency f_{max}, under which the scheme works, is 500 kilo-hertz; should the frequency go higher, a break up of the starting pulses occurs. The delaying period between the exiting and the starting pulses can amount to 0.15 - 0.2 microsec. The entering resistance is $R_{vkh} = 1$ kilo-ohm. The duration of the pulse ≈ 0.3 microsec (on the level of 0.1 from amplitude of U) hardly changes when the load R_n changes between 20 ohm and 3 kilo-ohm.

The amplitude of the starting pulses does not depend on the resistance of the load.

The remaining work characteristics of the pulse shaper are given in Fig. 3.

Tolerances in the feed voltages amount to ± 15 percent.

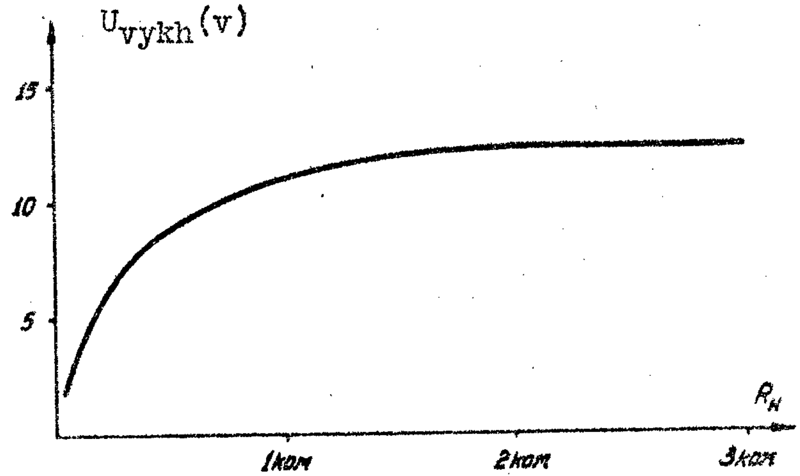

Fig. 2
Diagram of the dependence of the starting signal from the load under which the pulse-shaper works at E_1= -20 volt.

2. Operation of the Sub-circuit R-Diode-C

Fig. 7 shows the set-up of the circuit R-diode-C which insures the feeding of the collector circuit of the triode. The diode keeps open if the constant component of the current passing through collector's circuit does not exceed a certain maximum value of $I_{ko\ max}$, while the voltage at the point A runs lower than E_1 by the amount of the voltage drop U_D at the diode D. By neglecting the magnitude $U_D \ll E_1$, we can assume that the voltage at A is equal E_1. Should the collector current I_{ko} exceed the value $I_{ko\ max}$, the diode closes and the voltage in A becomes $|U_A| = |E_2| - I_K R$. This voltage is lower than E_1. The excess of the collector current I_{ko} over $I_{ko\ max}$ may occur in two cases. First: if the yield of the shaper's set-up $I_k \pm I_i > I_{ko\ max}$; Secondly: if the triode happens to run hot. In this case an auto-heating of the triode may develop with a decrease in the collector's resistance and an increase in its contact current. Under these conditions the sub-circuit R-diode-C has to limit the permissible current in the collector, or to sharply reduce the resistance in the source feeding this curcuit of the triode's collector, which is equivalent. Thus the

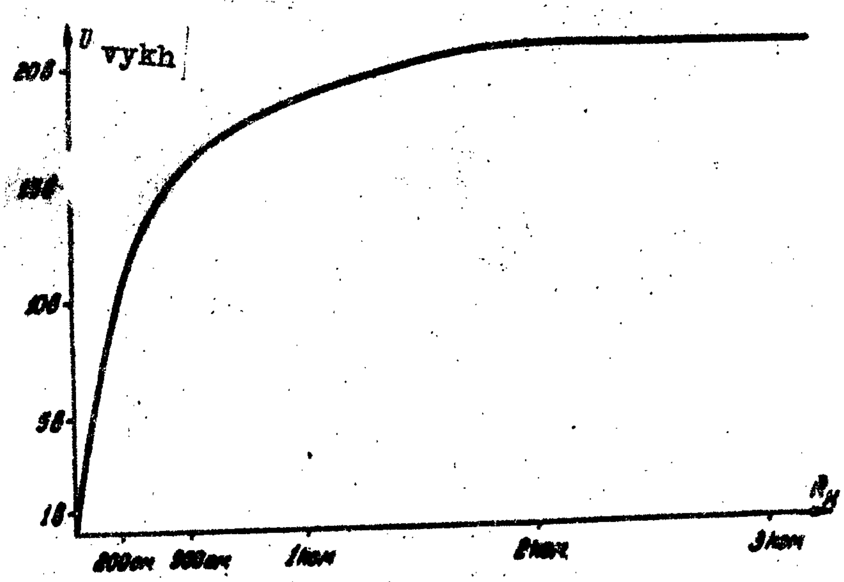

Fig. 3
Diagram of the dependence of the starting signal on the load under which the pulse-shaper works at $E_1 = -30$ volt.

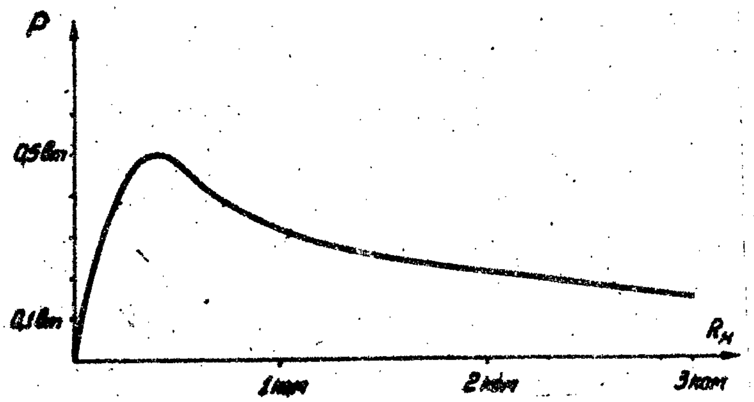

Fig. 4
Diagram of the power of the exiting pulse of the pulse shaper depending on the load for $E_1 = -30$ volt.

sub-circuit R-Diode-C ceases to be the source of voltage E_1 with $I_k < I_{ko\ max}$ and becomes the source of current for $I_k > I_{ko\ max}$. In this case the magnitude of the

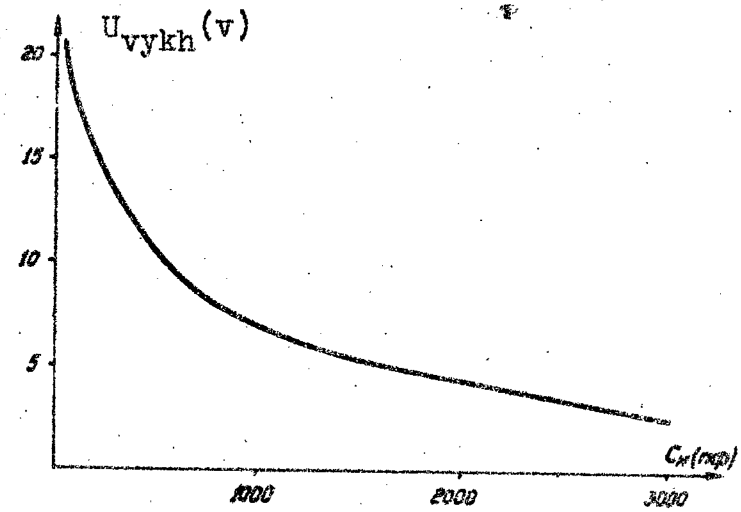

Fig. 5
Dependence of the exit signal on the pulse-shaper's capacity's load.

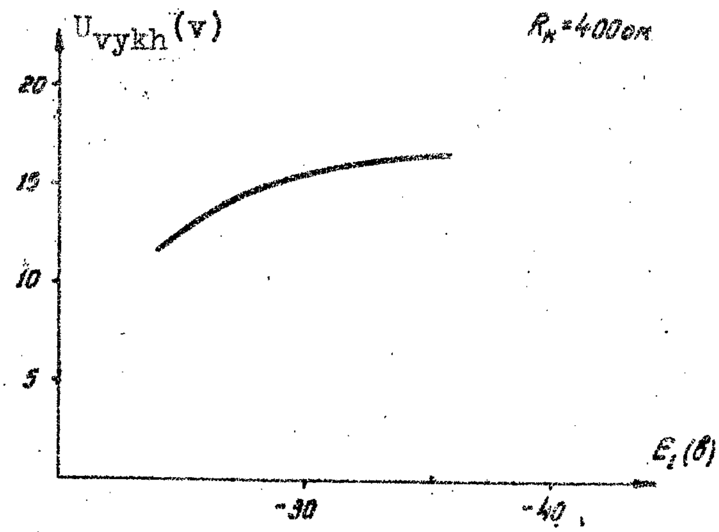

Fig. 6
Dependence of the exit signal on the change in the EMF E_1.

constant collector current is determined as follows:

$$I_{K} = \frac{E_2}{R + R_{0\ \text{triode}}},$$

where R_0 of the triode represents the triode's resistance to constant current under a raised temperature run.

Resistance R plays the part of a stabilizer of the collector current for $I_k > I_{ko\ max}$. An excess may take place when the temperature of the surrounding medium goes up. Thus the circuit R-Diode-C acts as a stabilizer of temperature also. In the first case mentioned, when $I_k = I_i > I_{ko\ max}$, the time, during which the temperature is excessive, equals the duration of the shaper's exit-pulse. In this case the capacity C forms an auxiliary source of energy and, with the C properly selected, the voltage at A does not change by more than a definite value ΔU_{c_1}. After the pulse fed from the capacity C is completed, the voltage at A comes to its previous value, before another pulse arrives (for a frequency of the order of 500 khz).

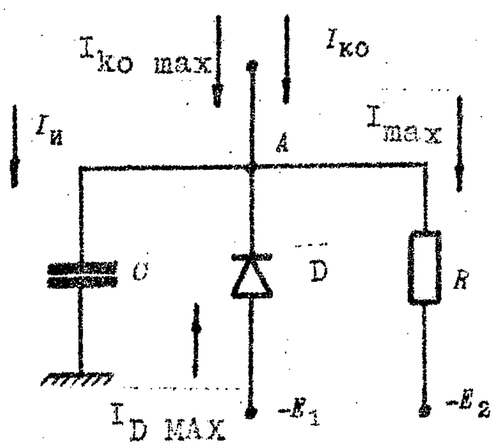

Fig. 7

I_{ko} is the dark current of the triode $I_{ko\ max}$ the maximum constant current of the triode at a frequency of 500 khz; I_{max} the maximum constant current permissible through the triode; I_1 the current of the exit-pulse of the triode.

Let us determine the values of the resistance R, capacity C, and voltage of the source E_2. The basic data are: values of currents I_1; I_{max}; $I_{ko\ max}$; $I_{D\ max}$; and the values of E_1 and ΔU_{c_1}. The relationship between these currents are $I_{ko} < I_{ko\ max} < I_{D\ max} < I_{max} < I_1$.

The time-diagram of the voltage at the capacity C is given in Fig. 8.

The basic relationship between the initial values are (see Figs 7, 8):

$I_{\text{макс}} \geq \frac{E_2}{R_Д}$ (1) $E_2 - E_1 \geq I_{Д\,\text{макс}}R + U_Д$ (2) $\Delta U_c \leqslant \Delta E(1 - e^{-\frac{\tau_1}{RC}})$ (3)

ΔU_c is the change of voltage on the capacity C for the period

$$\Delta E = E_2 + \Delta U_{c_1} - E_1 - I_{\text{ко макс}}R - U_Д ;$$

U_D is the voltage on the diode during the passing through it of the current $I_{D\ max}$.

$$U_Д << |E_2 - E_1|.$$

$$\Delta U_{c_1} = \frac{1}{C}\int_0^{\tau_и} I\ dt \qquad (4)$$

$$\Delta U_{c_1} \leqslant a = \text{const} \ , \qquad (5)$$

where ΔU_{c_1} is the voltage change on the capacity during the action of the pulse τ_1.

By putting $\Delta U_{c_1} = \Delta U_c$ the inequality (3) can be presented in the form:

$$\Delta U_c \leqslant \Delta E'(e^{\frac{\tau_1}{RC}} - 1), \qquad (6)$$

where $$\Delta E' = E_2 - E_1 - I_{\text{ко}\,max}R - U_Д \ .$$

Inequality (1) limits the maximum collector current; the realization of the inequality (2) insures that the current through the diode $I_{D\ max}$ will not be less than $I_{ko\ max}$.

Inequality (3) connects the law of the voltage change on the capacity C after the completion of the pulse, with the interval of time τ_1 during which the voltage changes which cannot be less than some definite magnitude ΔU_c.

Equality (4) determines the voltage change on the capacity C through the duration of the pulse τ_1.

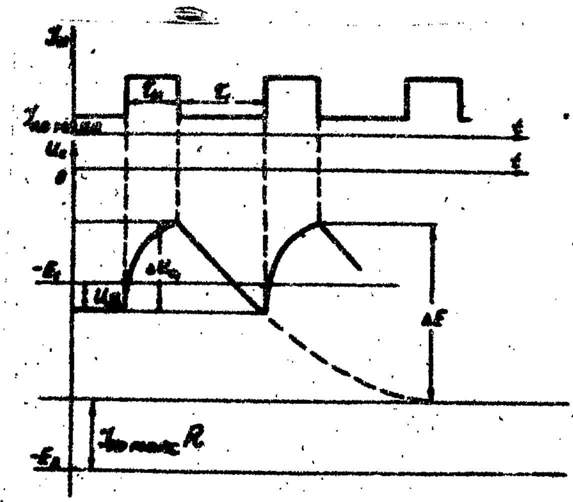

Fig. 8

ΔU_{C_1} is the voltage change on the capacity C during the time τ_1 (time of the passage of current I_1); ΔE is the maximum change of the voltage on C after the completion of I_1; it determines the run of the exponent in the interval τ_1.

Equality (5) represents the demand for the change of voltage on C during the pulse τ_1.

Let us assume that the current I_1 during the pulse is constant, while the actual duration τ_1' of the pulse is replaced by the equivalent duration τ_1 of the pulse, then the equality (4) will take the form:

$$\Delta U_{C_1} = \frac{I_1 \tau_1}{C}. \quad (7)$$

This equality is correct if the condition $I_1 \neq f(C)$ is realized and in the further account such realization will be taken for granted.

Solution of the basic relationships (1) to (5). Let us examine the possibility of simultaneous solution of these relationships and determine the region of this solution. Let us consider conditions (3) and (4). We begin by building the ratio

$$\sigma = \frac{\Delta U_C}{\Delta U_{C_1}}$$ that equals

$$\sigma = (1 - e^{-\frac{\tau_1}{RC}}) + \frac{\Delta E'(1 - e^{-\frac{\tau_1}{RC}})}{\frac{I_И \tau_И}{C}} . \qquad (8)$$

The limits of σ as it depends on C are:

$$\lim_{C \to 0} \sigma = 1 . \qquad (9)$$

$$\lim_{C \to \infty} \sigma = \frac{\tau_1 \Delta E'}{R I_И \tau_И} . \qquad (10)$$

Fig. 9 presents the likely position of the curves corresponding to the inequalities (3) and (4).

It is obvious that the conditions are realizable if $\sigma > 1$.

Now we shall examine the inequalities (1) and (2). Their graphic solution is given in Fig. 10.

Let us bring the inequality (3) to a shape explicit in reference to E_2 for the case of the equality $\Delta U_C = \Delta U_{C_1}$ and we will obtain:

$$E_2 > E_1 + I_{КО\,макс} R + \frac{\Delta U_C}{e^{\frac{\tau_1}{RC}} - 1} . \qquad (11)$$

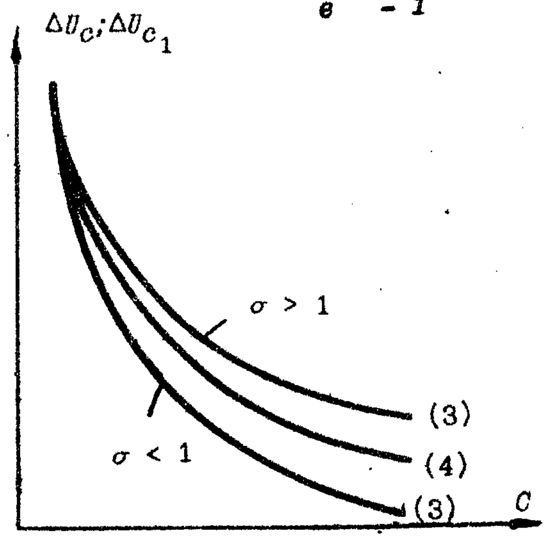

Fig. 9

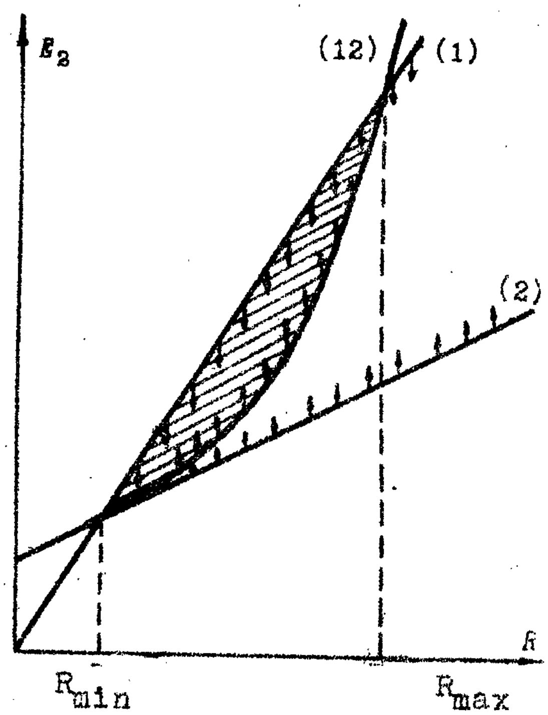

Fig. 10
Boundary values of R_{max} and R_{min} for R within which the simultaneous solution of the inequalities is possible (1), (2), (3), (4).

We shall neglect the values $U_D \ll E_1$ and $U_D \ll I_{ko\ max} R$. Let us change the current $I_{ko\ max}$ for a larger one $I_{D\ max}$. With the inequality (11) forming the condition for the selection of E_2, we intensify that inequality bringing it to the shape:

$$E_2 \geqslant E_1 + I_{Д\,макс} R + \frac{\Delta U_c}{e^{\frac{\tau_1}{RC}} - 1} \qquad (12)$$

We put $\Delta U_{c_1} = \frac{I_и \tau_и}{C}$ into the inequality (12) and obtain:

$$E_2 \geqslant E_1 + I_{Д\,макс} R + \frac{\frac{I_и \tau_и}{C}}{e^{\frac{\tau_1}{RC}} - 1} \qquad (13)$$

Thus inequality (13) includes the conditions of (3) and (4). It is evident that a simultaneous solution of inequalities (1), (2) and (13) becomes feasible if we satisfy the inequality*

$$|R(I_{\text{макс}} - I_{\text{Д макс}}) - E_1| > \frac{\frac{I_{\text{н}}\tau_{\text{н}}}{C}}{e^{\frac{\tau_1}{RC}} - 1}. \qquad (14)$$

The simultaneous solution of (4) and (5) yields the value of C. For this value of C, depending on the resistance R, the right side of (14) is evaluated. Should the inequality be realized, the problem can be considered solved.

Thus the feasibility of a simultaneous solution of relationships (1) to (5) is demonstrated.

Examination of expression (14). Further consideration of the simultaneous solution of basic relationships leads to the examination of the right side of (14).

We shall denote

$$\frac{\frac{I_{\text{н}}\tau_{\text{н}}}{C}}{e^{\frac{\tau_1}{RC}} - 1} = \gamma. \qquad (15)$$

Examining the magnitude γ as a function of C, we find that it represents the relation of a hyperbolic function to one approaching an exponent. It can be shown that γ will change much slower with the change in C than with the change in R.

We transform the expression for γ into the shape

$$\gamma = \frac{\frac{I_{\text{н}}\tau_{\text{н}}}{C}}{e^{\frac{\tau_1}{RC}} - 1} = \frac{\frac{I_{\text{н}}\tau_{\text{н}}}{C}}{\frac{\tau_1}{RC} + \sum_2^{\infty}\left(\frac{\tau_1}{RC}\right)^n \frac{1}{n!}} =$$

$$= \frac{\frac{\tau_1}{RC} R \frac{\tau_{\text{н}}}{\tau_1} I_{\text{н}}}{\frac{\tau_1}{RC} + \sum_2^{\infty}\left(\frac{\tau_1}{RC}\right)^n \frac{1}{n!}} = RI_{\text{н}}\frac{\tau_{\text{н}}}{\tau_1} \frac{1}{1 + \sum_2^{\infty}\left(\frac{\tau_1}{RC}\right)^{n-1}\frac{1}{n!}}. \qquad (16)$$

*Presented graphically, the inequality (14) expresses the fact that its right part added to the inequality (2) must not lie above the inequality for (1) in Fig. 10. Inequality (14) was formed from those of (1) and (12).

The magnitude $\sum_{2}^{\infty}(\frac{\tau_1}{RC})^{n-1}\frac{1}{n!}$ was computed for the range of $\frac{\tau_1}{RC} = 0.025 \div 2.5$ is shown by a graph in Fig. 11. In Fig. 11 we find the curve of error (its ordinate multiplied by 100 yields the error in percent) in the computation of the magnitude $e^{\frac{\tau_1}{RC}} - 1$ that results from limiting the serialization of $e^{\frac{\tau_1}{RC}}$ in powers of $\frac{\tau_1}{RC}$ by the first two terms.

The graph shows that the greater the value of RC, the smaller becomes the magnitude of

$$\sum_{2}^{\infty}(\frac{\tau_1}{RC})^{n-1}\frac{1}{n!}.$$

For instance, if $RC \geqslant \frac{\tau_1}{0.2} = 5\tau_1$ the value $\sum_{2}^{\infty}(\frac{\tau_1}{RC})^{n-1}\frac{1}{n!}$ equals 0.1.

Neglecting 0.1 in comparison to one unit, we find that practically the magnitude γ does not depend on the value of C, provided that the inequality $RC \geqslant 5\tau_1$ is realized.

If we neglect the magnitude $\sum_{2}^{\infty}(\frac{\tau_1}{RC})^{n-1}\frac{1}{n!}$ in comparison with one unit in the expression (16), we can obtain the first approximation to the value of R from the expression:

$$R \geqslant \frac{E_1}{\Delta I - I_2\frac{\tau}{\tau_1}}, \qquad (17)$$

where

$$\Delta I = I_{\text{макс}} - I_{Д\text{макс}}.$$

The resulting error in the value of γ cannot be computed without using the concrete values for C and R, even if it were only because the numerator in the expression for γ contains the value of C. For this reason we shall conduct our reasoning on general lines, and we shall show that the value of R computed from (17) shall always exceed the true value of R (as computed by taking into consideration $\sum_{2}^{\infty}(\frac{\tau_1}{RC})^{n}\frac{1}{n!}$.

Let us suppose that the neglected terms of the series mentioned equal I, i.e., $I = \sum_{2}^{\infty}(\frac{\tau_1}{RC})^{n}\frac{1}{n!}$. In such a case the denominator can be written as: $e^{\frac{\tau_1}{RC}} - 1 = \frac{\tau_1}{RC} + I$, or if we use

the ratio $\frac{I}{\frac{\tau_1}{RC}} = a$, we obtain $e^{\frac{\tau_1}{RC}} - 1 = \frac{\tau_1}{RC}(1 + a)$.

For the expression $\gamma = \frac{\frac{I_H \tau_H}{C}}{\frac{\tau_1}{RC}(1+a)} = \frac{I_H \tau_H R}{\tau_1 (1+a)}$ and returning to the expression (14) we obtain: $R \geqslant \frac{E_1(1+a)}{\Delta I(1+a) - \frac{\tau_H}{\tau_1} I_H}$.

The magnitude a can be expressed in percent and represents the permissible error in the evaluation of the serialization of $e^{\tau_1/RC}$. We shall denote by R_N the value of resistance R computed from the last expression, if we use the sign of equality in it. We shall form the ratio of R/R_N, i.e., the ratio of R obtained from (17) with the further terms of the series $e^{\frac{\tau_1}{RC}}$ neglected, to R with all terms considered.

$$\frac{R}{R_N} = \frac{1 + Ka}{1 + a},$$

where

$$K = \frac{\Delta I}{\Delta I - \frac{\tau_H}{\tau_1} I_H}, \qquad a \geqslant 0 .$$

We shall note that K cannot be less than 1, for the opposite would disagree with the physical nature of the problem.

It is evident from the ratio R/R_N that R is always greater than R_N. Consequently, by using the expression (17) in evaluating R, we make the error of one digit only.

Conclusion regarding the work of the circuit R-Diode-C. Inequalities (1) and (2) characterize the conditions in the set-up in a stationary run and in the absence of pulses.

To the contrary, expressions (3) and (4) characterize the conditions of the set-up in the passage of the pulses, i.e., in the dynamic run. The constant of time in the circuit of RC can be so chosen as to exceed the time interval τ, between the pulses, than run with the maximum frequency (f_{max}), and thus there will occur no accumulation of charges on the capacity C during the series of pulses. This accumulation of charges on the capacity is affected above all by the value of R, and the least by the value of C. However, the degree of the effect of C changes with the change in the magnitude of the ratio $\frac{\tau_1}{RC}$.

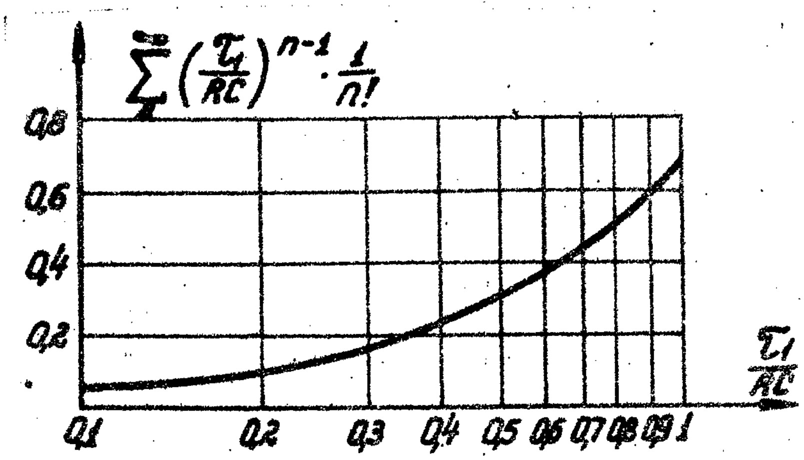

Fig. 11
Graph of the relationship between the value

$\sum_2^\infty \left(\frac{\tau_1}{RC}\right)^{n-1} \cdot \frac{1}{n!}$ and the ratio $\frac{\tau_1}{RC}$

The smaller the value of CR, the greater the effect of C. The permissible limits of the oscillation of voltage on the capacity C during the passage of pulses [see (5)] should not be enlarged when a simultaneous solution of the five initial expressions cannot be obtained. This would not bring a solution under reasonably permissible voltage oscillations on the capacity C.

On the contrary, a certain variation in the value of the maximum permissible current I_{max} in the positive direction, can rapidly widen the region of feasible solution. The region of simultaneous solution can also be enlarged by lowering the value of I_{Dmax}.

For the stationary run the percentage of energy coming from the sources and lost as heat in the resistance R is $\approx \frac{(E_2 - E_1)}{R_2}$. In order to reduce these losses it is advisable to useminimum values of E_2 and and maximum values of R.

3. Numerical computation of the circuit R-Diode-C

1. For currents I_{ko} and $I_{ko\ max}$. Starting from the actual measurements of these currents for a group of triodes (C2G) in a pulse shaper set-up during a stationary run on the frequency of 500 kilohz, we can assume that for the majority of the triodes these values do not exceed:

for $E_1 = -20$ volt for $E_1 = -30$ volt

for $I_{ko} = 3.5$ ma $I_{ko} = 4$ ma

$I_{ko\ max} = 5.5$ ma $I_{ko\ max} = 7$ ma

2. Maximum current through the diode D in a stationary run $I_{D\ max}$ is:

for $E_1 = -20$ volt for $E_1 = -30$ volt

$I_{D\ max} \geqslant 5.5$ ma $I_{D\ max} \geqslant 7$ ma.

3. Maximum current I_{max}. In determining this value one should proceed from the experiments in which the point-contact triodes were working under heavier currents than those guaranteed by the vendor.

Thus I_{max} must not be greater than 20 ma.

4. Current during the pulse I_1. It follows from the load characteristic of the pulse shaper that the range of current I_1 variations is 60 - 6 ma depending on the shaper's load.

5. The value of E_1. This is determined on the one hand by the required amplitude of the exit pulse and on the other, by the permissible voltage on the triode. This magnitude shall have two values:

$$E_1 = -20\ в \quad \text{and} \quad E_1 = -30\ в.$$

6. The magnitude ΔU_{c_1}. ΔU_{c_1} represents the loss of the useful voltage in the exit pulse of the shaper. We shall assume $\Delta U_{c_1} \simeq 1\ в$.

7. The value τ_1. For this computation, we shall determine the equivalent duration τ_1 given by the relationship $\frac{1}{C}\int^{\tau_И} I_И dt = \frac{1}{C} I_И \tau_И$ that is, assuming that the pulse current I_1 is constant for the duration τ_1, which amounts to 0.2 microsec.

Computation: 1) This computation is carried out for the following variants:

$$I.\ \text{for } I_И = 60\ ма \quad \begin{cases} I'.\ E_1 = -20в \\ I''.\ E_1 = -30в \end{cases}$$

$$II.\ \text{for } I_И = 30\ ма \quad \begin{cases} II'.\ E_1 = -20в \\ II''.\ E_1 = -30в \end{cases}$$

$$III.\ \text{for } I_И = 6\ ма \quad \begin{cases} III'.\ E_1 = -20в \\ III''.\ E_1 = -30в \end{cases}$$

Variant II reflects the conditions of the maximum efficacy of energy in the shaper's load for R_N = 400 ohm.

2) From the simultaneous solution of the expressions (4) and (5) we shall find the values of the capacity C (in microfarads)

I. $I_и$ = 60 ма $\qquad C_1 \geqslant 12\,000$ пф

II. $I_и$ = 30 ма $\qquad C_2 \geqslant 6000$ пф

III. $I_и$ = 6 ма $\qquad C_3 \geqslant 1200$ пф

3) We compute the value of γ :

I. $I_и$ = 60 ма $\qquad C_1$ = 12 000 пф

R(ком)	1	2	3	4	5	6	7	8	9	10
γ	7,7	15,6	23	31	40	48	56			

II. $I_и$ = 30 ма $\qquad C_2$ = 6000 пф

R(ком)	1	2	3	4	5	6	7	8	9	10
γ	4		12	16	20	23	27	32	36	40

III. $I_и$ = 6 ма $\qquad C_3$ = 1200 пф

R(ком)	1	2	3	4	5	6	7	8	9	10
γ	0,4	1,15	1,9	2,8	3,6	4,3	5			7,8

4) Using identical nets of coordinates, we shall build simultaneously the relationships of the expressions (1) and (13) (in Fig. 12).

The construction amounts to two variants: one for E_1 = - 20 volt, another for E_1 = -30 volt, while the current I_i amounts to 60, 30 and 6 ma.

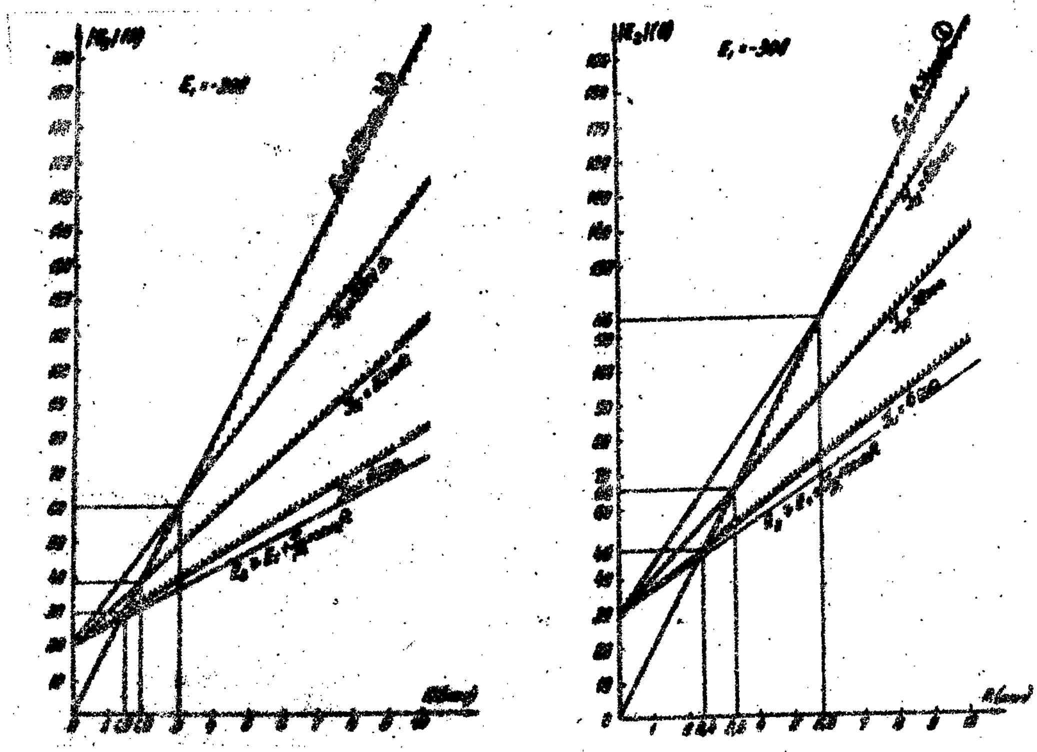

Fig. 12
Graphic presentation of the solution of basic relationships (1) to (5) in their application to the work conditions of a pulse shaper on a point contact triode for various runs of that work.

Fig. 12 shows that the minima value of E_2 and R

for $E_1 = -30$ *в*

I. $I_н = 60$ *ма* $\begin{cases} E_2 \geqslant 116 \text{ в} \\ R \geqslant 5{,}8 \text{ ком} \end{cases}$

II. $I_н = 30$ *ма* $\begin{cases} E_2 \geqslant 66 \text{ в} \\ R \geqslant 3{,}3 \text{ ком} \end{cases}$

III. $I_н = 6$ *ма* $\begin{cases} E_2 \geqslant 48 \text{ в} \\ R \geqslant 2{,}4 \text{ ком} \end{cases}$

for $E_1 = -20$ *в*

$$\text{I. } I_и = 60 \text{ ма} \qquad \begin{cases} E_2 \geqslant 60 \text{ в} \\ R \geqslant 3 \text{ ком} \end{cases}$$

$$\text{II. } I_и = 30 \text{ ма} \qquad \begin{cases} E_2 \geqslant 38 \text{ в} \\ R \geqslant 1{,}9 \text{ ком} \end{cases}$$

$$\text{III. } I_и = 6 \text{ мм} \qquad \begin{cases} E_2 \geqslant 29 \text{ в} \\ R \geqslant 1{,}5 \text{ ком} \end{cases}$$

5) Let us evaluate approximately the power losses P_R in the resistance R and compare them with the energy consumption by the set-up itself. $P_{o\ skh}$ in the stationary $P_{o\ skh}$ and $P_{dyn\ skh}$ in the dynamic runs.

	$E_1 = -30$ в	$E_1 = -20$ в
I. $I_и = 60$ ма	$P_R = 1{,}27$ вт	$P_R = 0{,}53$ вт
II. $I_и = 30$ ма	$P_R = 0{,}39$ вт	$P_R = 0{,}17$ вт
III. $I_и = 6$ ма	$P_R = 0{,}135$ вт	$P_R = 0{,}053$ вт

For the stationary run we have:

$E_1 = -30$ в $\qquad P_{o\ cx} = 0{,}12$ вт

$E_1 = -20$ в $\qquad P_{o\ cx} = 0{,}07$ вт

And for the dynamic run at the frequency of 500 kilohz:

$E_1 = -30$ в $\qquad P_{din\ cx} = 0{,}21$ вт

$E_1 = -20$ в $\qquad P_{din\ cx} = 0{,}11$ вт.

2023

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END

FOR REASONS OF SPEED AND ECONOMY
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